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PARTICIPATION IN THE CONSOLIDATED INFRARED SPECTROMETER (CIRS)

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During the period under review, Owen pursued the question of a determination of $^{15}N/^{14}N$ in the atmosphere of Saturn, to be carried out by CIRS when Cassini is in orbit about the planet.

There are presently no determinations of this important isotope ratio in Saturn, but a study of the 10 μm spectral region of Jupiter has led to the identification of $^{15}NH_3$ lines with the short Wavelength Spectrometer (SWS) of ISO. The resulting determination was a value of $^{15}N/^{14}N = 1.9 \ ^{+0.9}/_{-1.0} \times 10^{-3}$ for this giant planet (Fouchet et al. 2000). This number is decidedly lower than the terrestrial value of 3.66×10^{-3} for molecular nitrogen in the Earth's atmosphere. It is much lower than a direct measurement of $^{15}N/^{14}N = 5 \ ^{+2} / _{-1} \times 10^{-3}$ in the solar wind by Kallenbach et al. (1998). The latter discrepancy is especially surprising in that Jupiter and the sun are expected to have identical isotope ratios: deep mixing on the sun that would dredge up products of nucleosynthesis from the solar interior is not known to occur. Both Fouchet et al. (2000) and Kallenbach et al. (1998) suggested that some as yet unknown fractionation process in Jupiter's upper atmosphere might act to enrich ^{14}N above the NH_3 clouds, at the 400 mb pressure level corresponding to the ISO observation.

A new measurement of the nitrogen isotopes on Jupiter has just become available from the in situ mass spectra recorded by the Galileo Probe Mass Spectrometer. It is $^{15}N/^{14}N = 2.3 \pm 0.3 \times 10^{-3}$ (Owen et al. 2001). This determination refers to a pressure level greater than 0.8 mb, weighted toward 2 bars. This new result validates the essential correctness of the Fouchet et al. (2000) measurement while greatly reducing the uncertainty. It thus appears that the Kallenbach et al. (1998) value must somehow be in error. Further support for this conclusion comes from the upper limit of $^{15}N/^{14}N < 2.8 \times 10^{-3}$ set for solar wind nitrogen implanted in lunar grains (Hashizume et al. 2000).

We are thus in a position to use the nitrogen isotopes to constrain models for the origin of planets and planetesimals. Terzieva and Herbst (2000) have shown that ion-molecule reactions in interstellar clouds will enrich ^{15}N in compounds like HCN and NH_3 by as much as 30% compared with the value in N_2, the main reservoir of nitrogen in interstellar space. This explains the difference between the $^{15}N/^{14}N = 3.1 \; ^{+0.5} / _{-0.4} \times 10^{-3}$ measured in comet Hale-Bopp's HCN (Jewitt et al. 1997) and the new value measured in Jupiter, if Jovian nitrogen originally reached the planet in the form of N_2. Owen et al. (1999) showed that N/H is as enhanced as C/H and S/H on Jupiter, relative to solar values, requiring that nitrogen must have been delivered as N_2, as this was the dominant original reservoir of nitrogen in the solar nebular. Hence there is good internal consistency in the nitrogen story at last.

The requirement for delivery of N_2 by icy planetesimals to Jupiter is not a trivial point, since it is not immediately obvious how this can be accomplished. The two hypotheses currently under review are trapping at low temperature in amorphous ice (Owen and Bar-Nun, 1995; Owen et al. 1999), and incorporation as clathrate hydrates in crystalline ice (Gautier 2000). Both hypotheses require rather special conditions for planetesimal formation.

The next step is obviously to measure the nitrogen isotopes in another giant planet, and CIRS can do this at Saturn. By first making the measurement with CIRS at Jupiter, where we "know the answer", the remote sensing evaluation of $^{15}N/^{14}N$ from the NH_3 spectrum can be well calibrated. Thus when we carry out the same analysis of the ammonia spectrum at Saturn, we will be able to trust the answer. If we find the same ratio of isotopes as at Jupiter, we will have demonstrated that Saturn, like Jupiter, acquired its nitrogen primarily as N_2, with the concomitant constraints on the gas-carrying planetesimals. If the value of $^{15}N/^{14}N$ is different, new scenarios for the formation of Saturn will have to be developed.

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